Seawalls: An Overview Research Paper

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INTERTECT

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by

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INTRODUCTION

Seawalls are used primarily to protect areas in the rear of the beach against the effect of heavy storm action. They are necessarily massive and expensive. Seawalls limit the shoreward movement of the high water line, but under severe wave action they generally promote removal of sand from the beach by wave wash. Under normal wave action, this sand may be returned to the beach but the seawall has no capacity to retain the sand. The function of a seawall is to protect property and it has no value in stabilizing the beach.

The layout of seawalls is generally parallel to the shore. They should be placed as far back of the normal high water line as the development in the rear will economically permit. The minimum distance from the high water line is dependent on the width of beach required. The alignment of seawalls should be as straight as possible. Necessary changes in direction should be accomplished by gradual smooth curves to avoid concentration of wave forces at angles.

DESIGN

Seawalls are retaining walls which in addition to earth pressure from the land side are acted upon by the impact forces of the storm waves. On the shores of protected bays, the wave effect is slight and comparatively light structures will provide protection. In exposed locations, however, only massive well-founded structures will answer the purpose. Determination of the proper height of a seawall requires consideration of the character and extent of the development in the area to be protected, the maximum heights and frequency of the storm tides and waves, the elevation and character of the ground in the rear, and the probable effect of the groin system, if any, in accumulating sand. If the beach profile is high, the waves will break before reaching the seawall and their effect on the structure will be much reduced both in elevating the water level at the wall and in producing erosion along the toe of the seawall. It is important to place the foundations at a safe depth so that the material will not be lost from underneath the wall. Complete information on subsoil conditions is required. If rock underlies the site, at a reasonable depth, it is best to place the wall on it, the design following, in general, the principles of retaining wall design. Where the foundation is sand or other soft material it is recommended that the base of the wall be placed at or below the elevation of mean low tide, supporting it on piles and driving a row of sheet piling under the front toe to prevent loss of material by erosion from under the wall. It is customary to protect the toe of such walls by heavy riprap laid in five to six foot thicknesses and a width from ten to twenty feet. Protection from erosion along the toe of the wall is enhanced by the construction of groins which are often used for this purpose only.

In designing seawalls subject to overtopping by waves, it is important to protect the backfill from saturation and from the effects of heavy impact due to falling water. This may be done by shaping the face of the wall so as to turn back the waves without turbulence. Most seawalls built recently in the United States have a curved face, concave when viewed from the seaside, and often accentuated by a projecting coping. This type not only tends to reduce the lateral pressures on the wall by preventing saturation of backfill material, but also eliminates the back draft of receding waves occurring on straight-faced walls. Open joints or weep-holes across the seawall should not be permitted above low tide level regardless of the character of the backfill. During wave action, water- and air-filled confined spaces in the wall are subjected to pressures of great intensity. When wave action ceases, the compressed air in these spaces suddenly expands and may bring about destruction of the structures.

In an analysis of the forces exerted by waves on the seawall, it is first necessary to decide if the waves will break against, or immediately in front of, the structure. Forces due to non-breaking waves will essentially be hydrostatic, whereas breaking waves exert additional pressures due to the dynamic effects of turbulent water motion and entrapped air pockets. Evidence from various sources, including analyses of existing structures, suggests that pressures due to breaking waves will be in the range of 2,000 to 10,000 pounds per square foot. However, no generally-accepted analytical methods have been devised whereby they can be predicted with any great confidence.

According to Miniken, the total pressure on the seawall from breaking waves is a combination of dynamic and hydrostatic pressures. The <u>maximum</u> dynamic pressure, in pounds per square foot, occurs at still-water level and is given by

$$p_1 = \pi \gamma H \frac{d}{\lambda_0} \left(1 + \frac{d}{d_0} \right) \qquad \text{(EQUATION 1)}$$

where p_1 = maximum dynamic pressure, psf
d = depth of water at structure, ft
d_0 = deep-water depth, ft
λ_0 = wavelength in d_0, ft
H = height of wave just breaking on structure, ft
γ = specific weight of water (64.4 pcf for salt water)

This equation is often used for the case in which the sea bed rises steeply (in excess of 1 in 20) from deep water up to the face of a vertical wall.

The total dynamic force on the seawall (per horizontal foot) is often approximated as $p_1H/3$.

The total hydrostatic force of the water on the seawall (per horizontal foot) is equal to

$$p_2 = \frac{\gamma H}{2}\left(d + \frac{H}{4}\right) \qquad \text{(EQUATION 2)}$$

The total force on the wall (per horizontal foot) is the sum of the total dynamic (approximately, $p_1H/3$) and the total hydrostatic force (equation 2).

A number of theories and formulas have been developed for the determination of pressure of waves on vertical walls for the purely oscillatory wave conditions. This is, in fact, the non-breaking case. The theory of Sainflou gives a close approximation to the actual wave force that acts against the vertical face of a wall or breakwater. Although this methodology is commonly used, it is assumed here that the sea walls under consideration will be subjected to breaking waves as opposed to non-breaking waves and therefore any discussion of the theory of Sainflou will be omitted.

In addition, there are two other methods for predicting the maximum pressure on a seawall. One is called the Bagnold method, the other is referred to simply as the "Momentum Method." However the source of these two methods states neither of these methods on its own can be relied upon in any particular case, and that the results should be checked by comparison with the performance of existing structures in similar situations, supplemented for large and important projects by model testing. For this reason, the method of Miniken has been discussed in detail. Additional research into the methods of Sainflou, Bagnold, and the "Momentum Method" can be done if this becomes necessary.

MATERIALS

Heavy-duty seawalls are predominantly constructed of mass concrete and lighter ones almost exclusively of reinforced concrete. Seawalls of the latter type were built with stepped faces with good results in breaking up the up-rushing waves and thus reducing their adverse effect on the wall. Because of the detrimental effect of sea water on poor quality concrete, special precautions must be made to produce the densest and strongest concrete possible. Seawalls may be built of concrete, steel and timber or a combination of these materials of adequate strength and durability. Figure 1 shows examples of seawalls at Coney Island, New York (a and b); Brooklyn Parkway, New York (c); Ocean Beach Esplanade, San Francisco (d); Galveston seawall (e); Bayshore seawall in Tampa, Florida (f); and Hampton Beach seawall in New Hampshire (g).

WAVE FORECASTING

General observations have been made about the order of magnitude of maximum significant wave height for such bodies of water as the Atlantic Ocean (45 ft.), the Pacific Ocean (60 ft.), the Mediterranean Sea (20 ft.), the Black Sea (30 ft.), the Great Lakes (25 ft.), and the Gulf of Mexico (40 ft.). It should be noted that great expanses of water such as oceans do not necessarily produce waves of proportionally greater height than much smaller bodies such as the Gulf of Mexico or the Great Lakes. Ocean storms are generally more or less local and the very long distance to land is not a controlling factor. Their effects are sometimes felt long distances away in the form of swells, which are waves generated by storms occurring outside the area of observation.

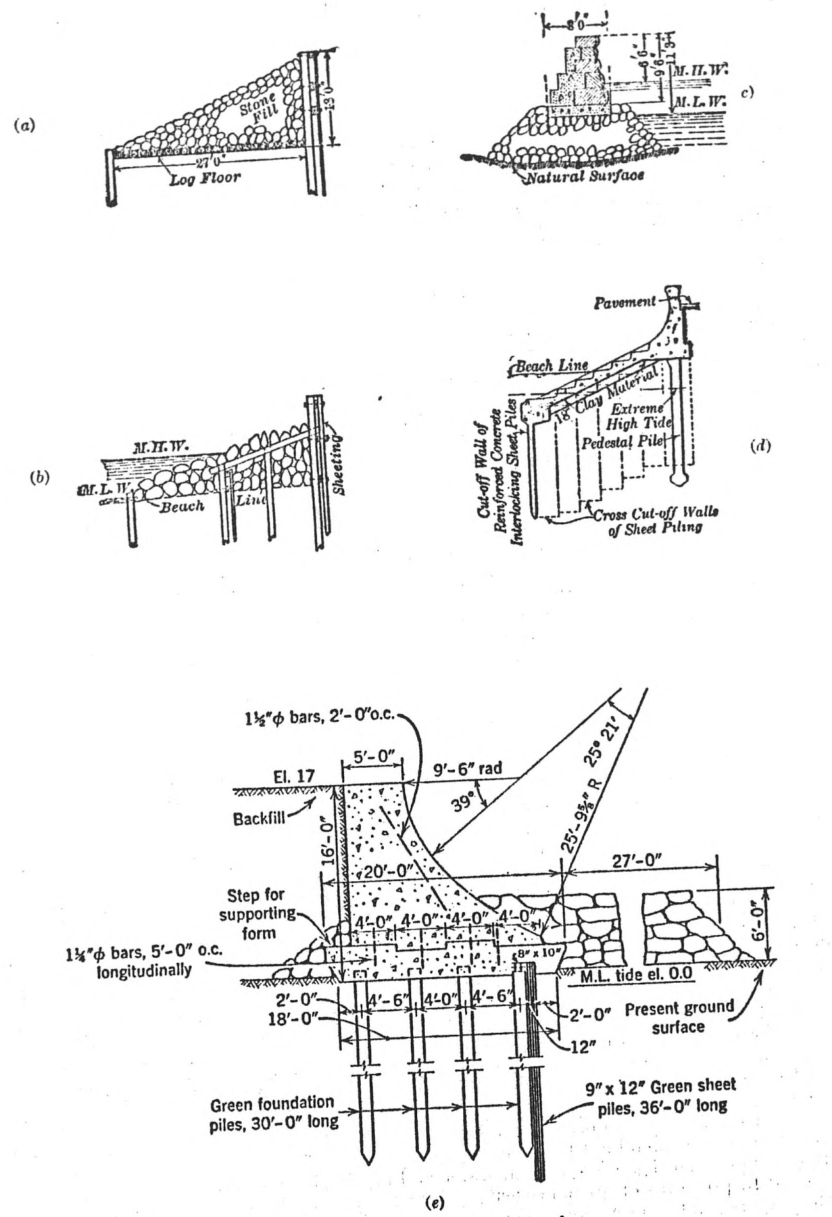
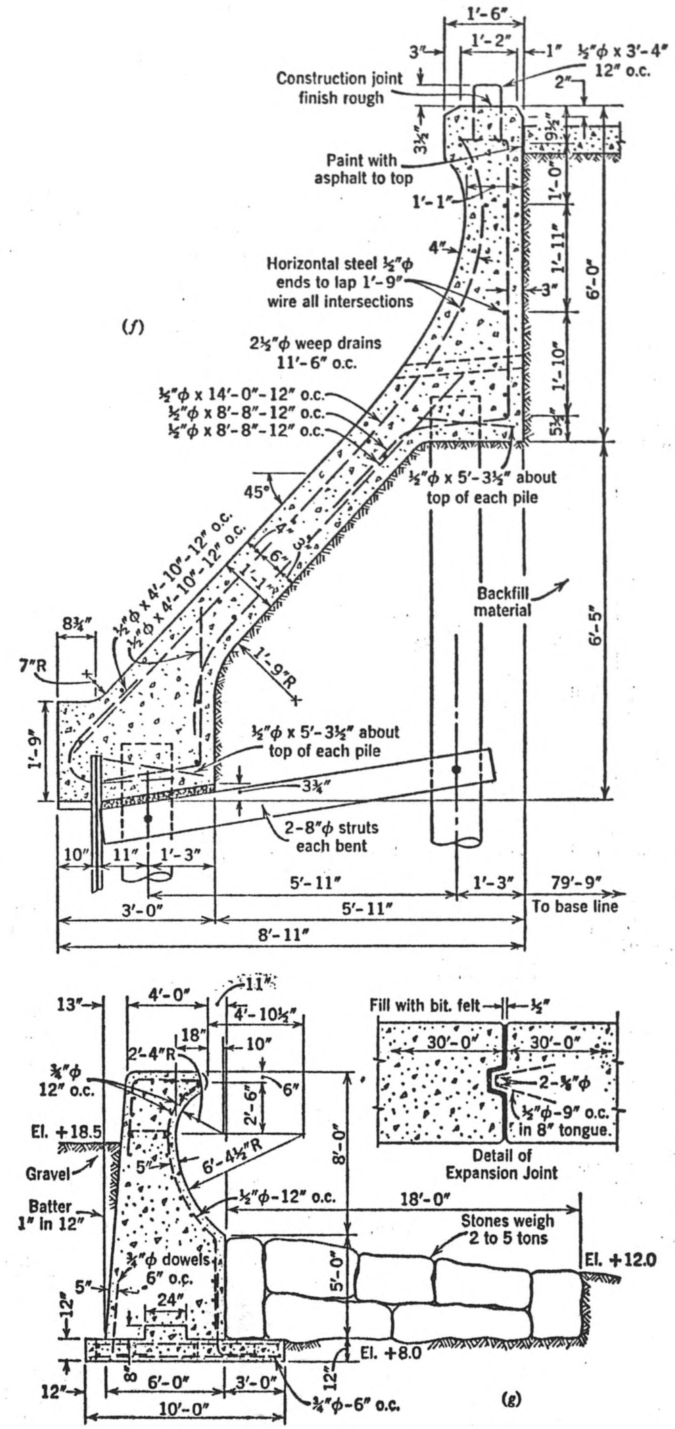


FIG. 19. Sea walls and bulkheads



In making observations on wave height for design purposes, it is important to note that, in a train of waves, the height of individual waves will vary greatly. The average height of the highest one-third of the waves for a stated interval has been termed the significant height, and it has been found that the highest or maximum wave has a height about 1.87 times the significant height.

The methodology for forecasting waves depends on several factors, all of which are interrelated in a relatively complex process. These include the fetch (Fetch is the horizontal extension or width of a storm's generating area for waves.), the wind velocity and direction, the wind duration, the water depth, the wave decay, the wave diffraction, the wave refraction, and the wave reflection. Once again, additional research into the methodology for forecasting waves can be done if this becomes necessary.

EPILOG

The above information is intended merely to be an introduction to some design considerations regarding the construction and function of seawalls. It is by no means intended to be an in depth analysis of the design process.